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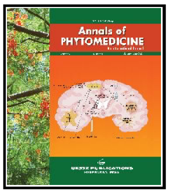

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Formulation and storage study of leather prepared from litchi (*Litchi chinensis* Sonn.) fruit affected with pericarp browning using response surface methodology (RSM)

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Abstract

Besides the numerous health benefits and nutritional properties of litchi, lot of postharvest losses occur every year because of its perishable nature. Many strategies are needed to reduce the substantial fruit loss in litchi during its peak season. Fruit leather has the potential to increase fruit solid consumption, especially in youth. The purpose of this study was to develop fruit leather from litchi affected with pericarp browning and evaluate its shelf-life. Box-Behnken design was used to assess the effects of sugar (25-50 %), citric acid (0.5-2 %), and pectin (0.5-1.5 %) on sensory parameters of litchi leather and data was analyzed by using software Design-Expert 8.0.7.1. The results revealed that there were significant differences (p=0.05) in appearance, color, odor, taste, texture and overall acceptability of freshly prepared litchi leather. Based on sensory analysis fruit leather prepared from 50 % sugar, 0.8 % citric acid and 1.5 % pectin, showed the best organoleptic characteristics and scores for various parameters were above 8.0. The selected product was stored at ambient temperature for 12 months and was evaluated at an interval of 2 months. During storage, acidity and nonenzymatic browning increased significantly (p=0.05) while TSS and moisture showed nonsignificant effects. Sensory parameters except for odor also showed significant changes (p=0.01) during the storage period of one year. Hence, the preparation of leather can be an effective way of utilizing litchi having brown pericarp, preventing economical loss to farmers as well as conserving their nutrients in concentrated form for a long period of time.

1. Introduction

Fruits are generally considered as protective food because they are extensively rich in antioxidants, phytochemicals, vitamins and minerals, which are effective in the prevention of various diseases. According to Chellammal (2022), 400 g of fruits and vegetables in regular diets improves health and rejuvenates the human system. Litchi (*Litchi chinensis* Sonn.) is delicate and highly perishable fruit, with high commercial value because of worldwide consumption. The fruit has white and translucent fleshy aril surrounded by bright red and attractive pericarp. The whole fruit of litchi has great medicinal value. It is a rich source of various phytochemicals, vitamins (vitamin C, niacin, riboflavin, thiamine, folate and β-carotene) minerals, dietary fibres, and many bioactive compounds such as quercetin and kaempferol. Reports have shown that arils and seeds of litchi obstruct the growth of cancer cells due to the presence of good content of flavonoids (Bhat and Al-daihan, 2014; Xu *et al*., 2011). In addition, the ethnopharmacological history of litchi indicated that it possesses hypoglycemic, anticancer, antibacterial, antihyperlipidemic, antiplatelet, antitussive, analgesic, antipyretic, hemostatic, diuretic and antiviral activities (Sabrin and Gamal, 2015). Other health benefits, includes protection against oxidative stress, prevention and curing of hyperuricemia, depletion of fatigue and visceral fat (Kang *et al*., 2012; Ogasawara *et al*., 2009; Sakurai *et al*., 2008). Traditionally, arils of litchi fruit have been taken as a remedy for cough, diarrhea, stomach ulcers, diabetes, dyspepsia, obesity, and to kill intestinal worms (Sabrin and Gamal, 2015; Castellain *et al*., 2014; Liu *et al.,* 2007; Sayre, 2001). In addition, fruit is said to be diuretic, digestive, carminative, anti-febrile and tonic and used to relieve neural pain, dysentery and swelling (Ahmad *et al*., 2012). The pericarp of litchi taken as a tea helps to overcome smallpox eruptions and diarrhea (Lim, 2013; Li, 2009).

Besides many health benefits of litchi, lots of postharvest losses occur every year during harvesting, sorting, transportation and marketing because of its highly perishable nature. Hence, fruits are sent to market on the day of harvest to avoid physiological changes in fruit. These changes include browning of the pericarp within 1-2 days after harvest due to degradation of anthocyanins, which may be caused by pericarp polyphenol oxidase and peroxidase activities (Kumar *et al.,* 2016) accelerated by desiccation, mechanical injury and postharvest decay. These quantitative and qualitative

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losses in litchi fruits from the time of harvest to the final consumption not only reduce the availability of fruits but also increase the per-unit cost of transport and marketing. The chemical treatments are not sufficient to reduce the postharvest losses and have several disadvantages which include high cost, SO_2 fumigation intensified microcracking of the pericarp, presence of chemical residue in fruit, *etc*. which affect human health (Sivakumar *et al.,* 2005; Jiang *et al*., 2005). Desiccation and browning of skin may not affect the fruit but greatly reduce the commercial value of litchi in domestic and international markets (Kumar, 2016), nevertheless the arils still remain fit for consumption as suggested by Sangeeta *et al.* (2014). Such fruit may be converted into value added products such as osmo-air dried, leather, chutney, jam, *etc*. (Sangeeta *et al.,* 2016) with the purview to minimize huge economic losses occurring to growers and conserve the nutritive components of litchi. In recent years, consumers have become more health conscious in their food choices but have less time to prepare healthful meals. As a result, the market demand for "minimally processed" or "lightly processed" food has rapidly increased which helps in reducing post-harvest losses of litchi, concentrating nutritive value of litchi as well as enhancing the farmer's income during peak season and studying storage stability of the developed litchi fruit leather.

Fruit leather, also known as fruit bar or fruit slab is an important dehydrated fruit-based confectionery product that is prepared by drying fruit pulp with or without additions of ingredients like sugar, pectin, citric acid, maltodextrin, lecithin and preservatives (Demarchi and Giner, 2010; Phimpharian *et al.,* 2011; Diamante *et al.,* 2014). Drying and presence of enough sugar reduces the water activity of the leather to a safe level to improve its shelf life (Quintero *et al.,* 2012). Fruit leather is a nutritious and appealing product with longer shelf-life. Processing prior to drying is crucial to obtain high-quality fruit leathers. Heating is the most widely applied treatment before drying the fruit pulp. It helps in enzyme inactivation, microbiological decontamination and pulp concentration (Bandaru and Bakshui, 2020; Simao *et al.,* 2019). Many health benefits are associated with fruit leather such as a good source of nutrients, support in digestion as it is comprised of numerous fibres and assists in losing weight as it produces fewer calories (less than 100 kcals per serving), than many other snacks (Diamante *et al.,* 2014). Hence, this investigation was carried out with the objective to process the litchi fruits affected by pericarp browning for the development of leather.

2. Materials and Methods

2.1 Procurement of raw material

The fully ripened litchi fruits (Litchi chinensis Sonn.) cultivar Rose Scented was collected from the Horticulture Research Centre, *Pattarchatta* of G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar (Uttarakhand) during the peak season (June). Fruits were washed thoroughly with clean water and kept at ambient conditions till the development of brown color on the pericarp and then tested for various physicochemical and microbial analyses (total plate count and yeast and mould count). Sugar was purchased from local market of Pantnagar while pectin, citric acid and other chemicals required for the study were issued by the department of Food Science and Technology, College of Agriculture.

2.2 Preparation of litchi leather

Litchi affected with brown pericarp were peeled to remove the outer skin. Pulp was extracted with the help of a pulper. Pulp was mixed with varying levels of, sugar, citric acid and pectin (Table 1) and then boiled to form a thick paste-like homogenous mixture. The mixture was poured into aluminium trays (smeared with butter) in a thin layer (0.5-1 cm) and dried at 60 ± 2°C in a tray drier until the moisture content in the product was reduced to about 15 % (Srivastava and Kumar, 2003). The cooled litchi leather was cut into rectangular pieces and packed in butter paper followed by polyethylene packing (Figure 1).

Table 1: Coded and actual values of process parameters for processing of litchi leather

Experiment No.	Sugar		Citric acid		Pectin	
	%	Coded value	%	Coded value	%	Coded value
1	25	-1	0.5	-1	1	0
2	25	-1	2	+1	1	0
3	25	-1	1.25	0	0.5	-1
4	25	-1	1.25	0	1.5	+1
5	50	+1	0.5	-1	1	0
6	50	+1	2	+1	1	0
7	50	+1	1.25	0	0.5	-1
8	50	+1	1.25	0	1.5	+1
9	37.5	0	0.5	-1	0.5	-1
10	37.5	0	2	+1	0.5	-1
11	37.5	0	0.5	-1	1.5	+1
12	37.5	0	2	+1	1.5	+1
13	37.5	0	1.25	0	1	0
14	37.5	0	1.25	0	1	0
15	37.5	0	1.25	0	1	0
16	37.5	0	1.25	0	1	0
17	37.5	0	1.25	0	1	0

Litchi pulp
↓
Addition of finely ground sugar, pectin and citric acid
↓
Heating to dissolve sugar
↓
Spreading in aluminium tray
↓
Drying (60 ± 1^{0}C)
↓
Cooling
↓
Cutting into pieces
↓
Litchi leather

Figure 1: Flow sheet for making litchi leather.

2.3 Sensory evaluation

The prepared samples of litchi fruit leather were subjected to organoleptic evaluation (appearance, color, odor, taste, texture and overall acceptability) by 30 members of semi-trained sensory panel on the nine-point hedonic scale (Resende *et al.,* 2008; Torres *et al.,* 2015) and the ideal combination of sugar, citric acid and pectin were selected after analyzing the data on the software Design-Expert 8.0.7.1. The selected treatment was then packed in butter paper followed by polyethylene packaging and kept at ambient temperature for storage study of 12 months and was evaluated at an interval of 2 months.

Organoleptic evaluation was performed by a panel of 30 semi-trained judges using nine-point Hedonic Rating Scale where, 1 and 9 represented disliked extremely and liked extremely, respectively (Lawless and Heymann, 2010).

2.4 Experimental design and statistical analysis

Box Behnken Design of Response Surface Methodology (RSM) with three blocks for three factors was used for the optimization of different levels of sugar (X_1 = 25-50%), citric acid (X_2 = 0.5-2%) and pectin (X_3 = 1-1.5%) to prepare litchi leather. The design consisted of 17 treatment combinations, including 3 levels of each variable, which were fixed to allow the investigation of the wide range of experimental conditions within practical limits (Table 1). The observed responses for sensory parameters were regressed against sugar, citric acid and pectin levels for the second-order polynomial model as given below by using the software Design-Expert 8.0.7.1.

$$Y = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_{11}X_1^2 + \beta_{22}X_2^2 + \beta_{33}X_3^2 + \beta_{12} X_1X_2 + \beta_{13} X_1X_3 + \beta_{23} X_2X_3$$

where, Y is the response calculated by the model; X_1, X_2 and X_3 are coded values of independent variables; β_0 is the model coefficient; β_1, β_2 and β_3 are linear regression coefficients; β_{11}, β_{22} and β_{33} are quadratic regression coefficients and β_{12}, β_{13} and β_{23} are interactive regression coefficients (Sangeeta *et al.,* 2017). These models were analyzed for their adequacy on the basis of coefficient of multiple determinants (R^2), F-value, lack of fit and *p*-value. 3-D graphs were developed using the fitted quadratic polynomial models.

2.5 Physicochemical analysis

Arils of fresh litchi as well as brown pericarp litchi were subjected to physical and chemical analysis. Color of skin and arils was determined by visual observations. To determine specific gravity water displacement method was used as suggested by Sharma and Nautiyal (2009). Moisture and ash were determined by AOAC (2012) method. TSS was determined by Hand Refractometer and the readings were corrected to 20°C. Acidity and ascorbic acid were estimated by titration against 0.1 N NaOH using phenolphthalein as indicator and 2, 6-dichlorophenol indophenol, respectively as described by Ranganna (2011). Lane and Eynon method was used for the determination of sugars and nonenzymatic browning of preserved samples of litchi leather was estimated as described by Ranganna (2011).

2.6 Microbial analysis

The microbial analysis of raw litchi having brown pericarp and optimized litchi leather during storage was done by total plate count and yeast and mould count using the method described by Mudili (2007).

3. Results

3.1 Physicochemical and microbial analysis of litchi

Physicochemical attributes and microbial growth of fresh and brown pericarp litchi are presented in Table 2. It can be concluded that the external skin color of fresh litchi fruits was attractive red it completely turned to brown color within 48 hours (Figure 2). However, no change in the color of arils was observed. The changes in physicochemical characteristics such as the decrease in weight, specific gravity, moisture, acidity and ascorbic acid while increase in TSS after 2 days of storage were recorded but no microbial growth was observed in fresh as well as litchi affected with pericarp browning. So, that litchi having brown pericarp is of good quality and can be utilized to produce litchi leather.

Table 2: Physicochemical and microbial analysis of fresh litchi and after pericarp browning

Characteristics	Freshly harvested litchi	Litchi with brown pericarp*
Physicochemical		
Skin colour	Attractive red	Brown
Colour of arils	Milky white	Milky white
Fruit weight (g)	20.59 ± 0.41	19.60 ± 0.14
Specific gravity	0.99 ± 0.01	0.92 ± 0.05
Moisture (%)	81.20 ± 0.25	79.52 ± 0.87
TSS (%)	16.10 ± 0.99	16.94 ± 0.15
Acidity (%)	0.51 ± 0.01	0.49 ± 0.03
Ascorbic acid (mg/100 g)	28.72 ± 0.39	19.63 ± 0.55
Total sugars (%)	10.82 ± 0.01	10.99 ± 0.009
Microbial		
Total plate count (cfu/g)	ND	ND
Yeast & mould count (cfu/g)	ND	ND

*Pericarp browning developed after storage of fresh litchi at ambient conditions in the month of June. ND stands for not detected.

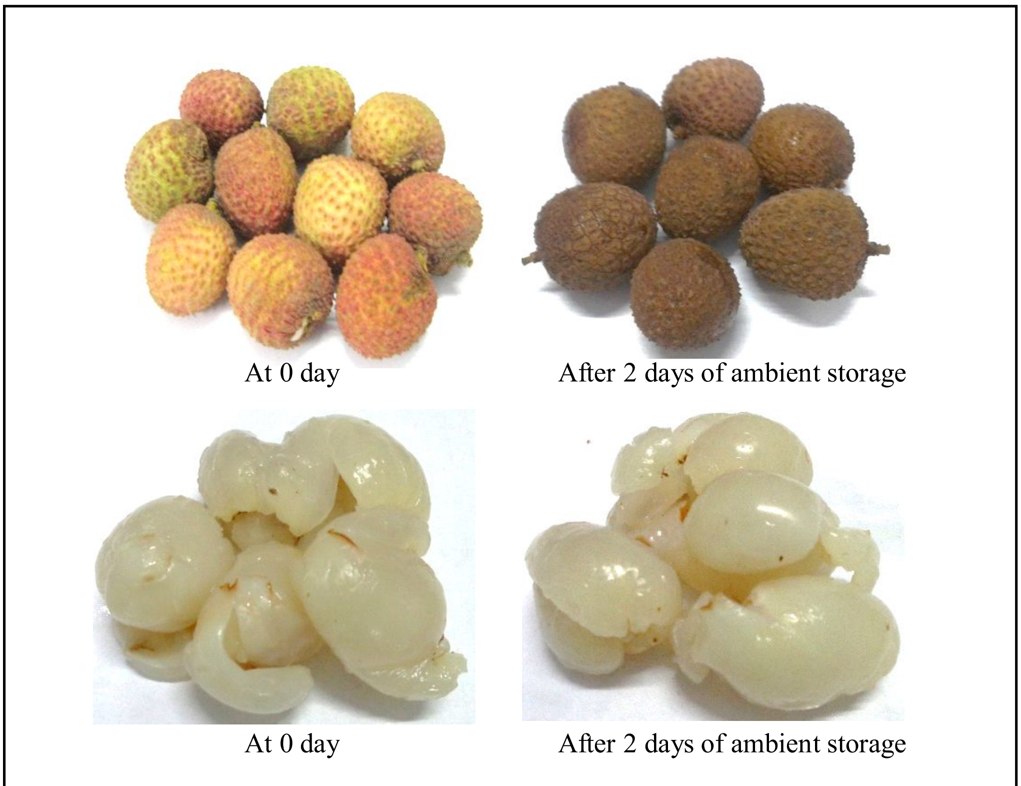


Figure 2: Effect of ambient storage on colors of external skin and aril of litchi fruit.

3.2 Effect of different concentrations of sugar, citric acid and pectin in the sensory scores of litchi leather

The complete experimental design in terms of coded values and their respective sensory responses are presented in Table 3. Regression equations and their estimated regression coefficients obtained based on this data are depicted in Table 4. All the coefficients of determination (R^2) for appearance, color, texture and overall acceptability are significant at $p \leq 0.01$ while taste and texture are at $p \leq 0.05$. The developed models pertaining to all the sensory attributes are significant as R^2 is more than 80% and lack of fit is nonsignificant. Analysis of variance for the full second-order polynomial model for sensory scores of litchi leather showed that F_{test} values were also more than F_{listed} which indicates the significance of the model for all sensory attributes (Table 4).

Table 3: Effect of different levels of sugar, citric acid and pectin on sensory scores of litchi leather samples

Experiment No.	Sensory scores*					
	Appearance	Color	Odor	Taste	Texture	Overall acceptability
1	6	6	8	8	7	7
2	6.5	6.5	4.5	4.5	6	6
3	7.5	7.5	5.5	5.5	6.5	5.5
4	7.5	7.5	5.5	5.5	5.5	5.5
5	7	7	6.5	6.5	7	7
6	7.5	7.5	5.5	5.5	5.5	6.5
7	5	5	7.5	7.5	4	4
8	8.5	8.5	8.5	8.5	8	8.5
9	5	5	8	8	5.5	5.5
10	5	5	5	5	4	4
11	8	8	8	8	7	7
12	7	7	6	6	5.5	5.5
13	5	5	7	7	6	6
14	5	5	7	7	6	6
15	5	5	7	7	6	6
16	5	5	7	7	6	6
17	5	5	7	7	6	6

* Average score given by 30 semi-trained panelists on nine point hedonic scale.

Table 4: Regression analysis of sensory parameters of litchi leather

Source		Appearance		Color		Odor		Taste		Texture		Overall acceptability	
		p-value	RC	*p*-value	RC	*p*-value	RC	*p*-value	RC	*p*-value	RC	*p*-value	RC
Model		0.0029	5	0.0057	5	0.0491	7	0.0491	7	<0.0001	6	0.0003	6
Linear	X_1	0.7294	0.06	0.06	0.06	0.0680	0.56	0.0680	0.56	0.1036	-0.06	0.0587	0.25
	X_2	0.4948	0.12	1.0000	0	0.0026	-1.18	0.0026	-1.18	<0.0001	-0.68	0.0014	-0.56
	X_3	0.0010	0.93	0.0012	1.06	0.3699	0.25	0.3699	0.25	<0.0001	0.75	<0.0001	0.93
Quadratic	X_{12}	0.0005	1.43	0.0022	1.31	0.2632	-0.43	0.2632	-0.43	<0.0001	0.43	0.0136	0.5
	X_{22}	0.2328	0.31	0.1623	0.43	0.2632	-0.43	0.2632	-0.43	0.2168	-0.06	0.4401	0.12
	X_{32}	0.0239	0.68	0.0230	0.81	0.6182	0.18	0.6182	0.18	<0.0001	-0.43	0.0046	-0.62
Interactive	X_1X_2	1.0000	0	1.0000	0	0.1341	0.62	0.1341	0.62	0.0331	-0.12	0.4512	0.12
	X_1X_3	0.0092	0.85	0.0187	0.87	0.5198	0.25	0.5198	0.25	<0.0001	1.25	0.0002	0
	X_2X_3	1.0000	0	0.4132	-0.25	0.5198	0.25	0.5198	0.25	1.0000	0	1.0000	0.5
Coefficient of determination (R^2)		92.93 %		91.28 %		82.64 %		82.64 %		99.61 %		96.28 %	
F value		10.22**		8.14**		3.70*		3.70*		201.26**		20.15**	
Lack of fit		NS		NS		NS		bNS		NS		NS	

X1= sugar (%); X2= Citric acid (%); X3= pectin (%)
**, * significant at 1% and 5% levels of significance, respectively
RC stands for Regression coefficient and NS stands for Nonsignificant
F 9, 7 = 6.72 (1%) and 3.68 (5%).

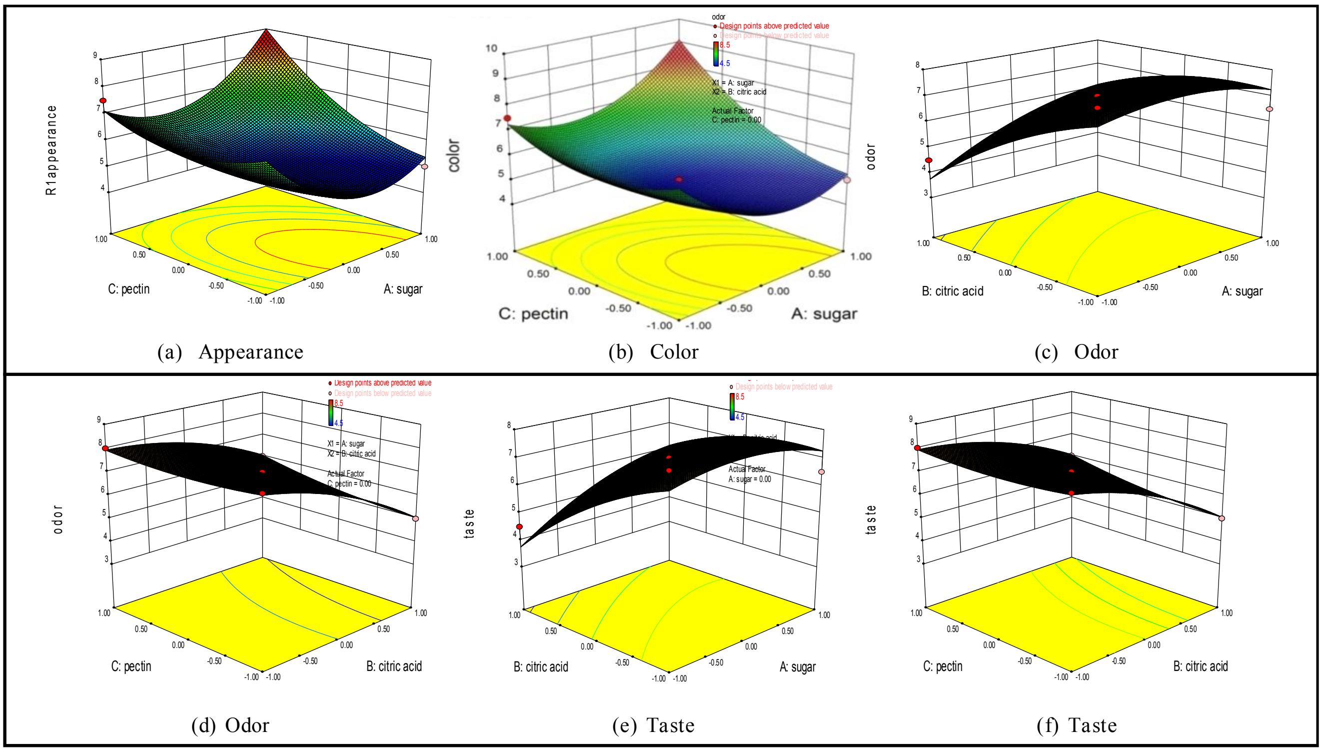
Sensory data of litchi leather were fitted into the second-order polynomial model and equations were obtained for each response as predicted in Table 5. Negative coefficient of citric acid (X_2) with regard to odor, taste, texture and overall acceptability, at the linear level, indicates decrease in responses when the level of the citric acid (X_2) is increased. Positive coefficient of pectin (X_3) at linear level indicates that increasing the level of pectin improves the rating of appearance and color. Positive interaction of sugar and pectin (X_1X_3) with respect to appearance, color, texture and overall acceptability scores indicates that the responses are minimum at centre point and it increases with increase or decrease of both the variables from centre point while significant negative interaction of citric and pectin (X_2X_3) with regard to texture suggests that the response is maximum at centre point and level of one of the predictors can be increased while that of other decreased for constant value of the response. In case of appearance, color, texture and overall acceptability, positive coefficient of sugar at quadratic term (X_1^2) indicates the minimum response at centre value of the parameter. Positive quadratic coefficient of pectin (X_3^2) with respect to appearance and color represents the minimum response at centre value of the parameter while negative coefficient of X_3^2 with regard to texture and overall acceptability indicates the maximum response at the centre value of the variables and it increases with increase or decrease in parameter level.

Table 5: Overall polynomial equations of sensory parameters of litchi leather

Sensory parameters	Overall polynomial equations
Appearance	$Y = 5+ 0.06X_1 + 0.12X_2+0.93X_3+ 0X_1X_2 + 0.85\ X_1X_3 + 0\ X_2X_3+ 1.43\ X_1^2+ 0.31X_2^2+ 0.68\ X_3^2$
Color	$Y = 5+ 0.06X_1 + 0X_2+1.06X_3+ 0X_1X_2 + 0.87\ X_1X_3- 0.25\ X_2X_3+ 1.31\ X_1^2+ 0.43X_2^2+ 0.81\ X_3^2$
Odor	$Y = 7+ 0.56X_1 - 1.18X_2+ 0.25X_3+ 0.82X_1X_2 + 0.25\ X_1X_3 + 0.25\ X_2X_3- 0.43\ X_1^2 - 0.43X_2^2 + 0.18\ X_3^2$
Taste	$Y = 7+ 0.56X_1 - 1.18X_2+ 0.25X_3+ 0.82X_1X_2 +0.25\ X_1X_3 + 0.25\ X_2X_3- 0.43\ X_1^2 - 0.43X_2^2 + 0.18\ X_3^2$
Texture	$Y = 6+ 0.06X_1 - 0.68X_2+ 0.75X_3- 0.12X_1X_2 + 1.25\ X_1X_3 + 0\ X_2X_3+ 0.43\ X_1^2+ 0.061X_2^2 - 0.43\ X_3^2$
Overall acceptability	$Y = 6+ 0.25X_1 - 0.56X_2+ 0.93X_3+ 0.12\ X_1X_2 + 0\ X_1X_3 + 0.5\ X_2X_3+ 0.5\ X_1^2+ 0.12X_2^2- 0.62\ X_3^2$

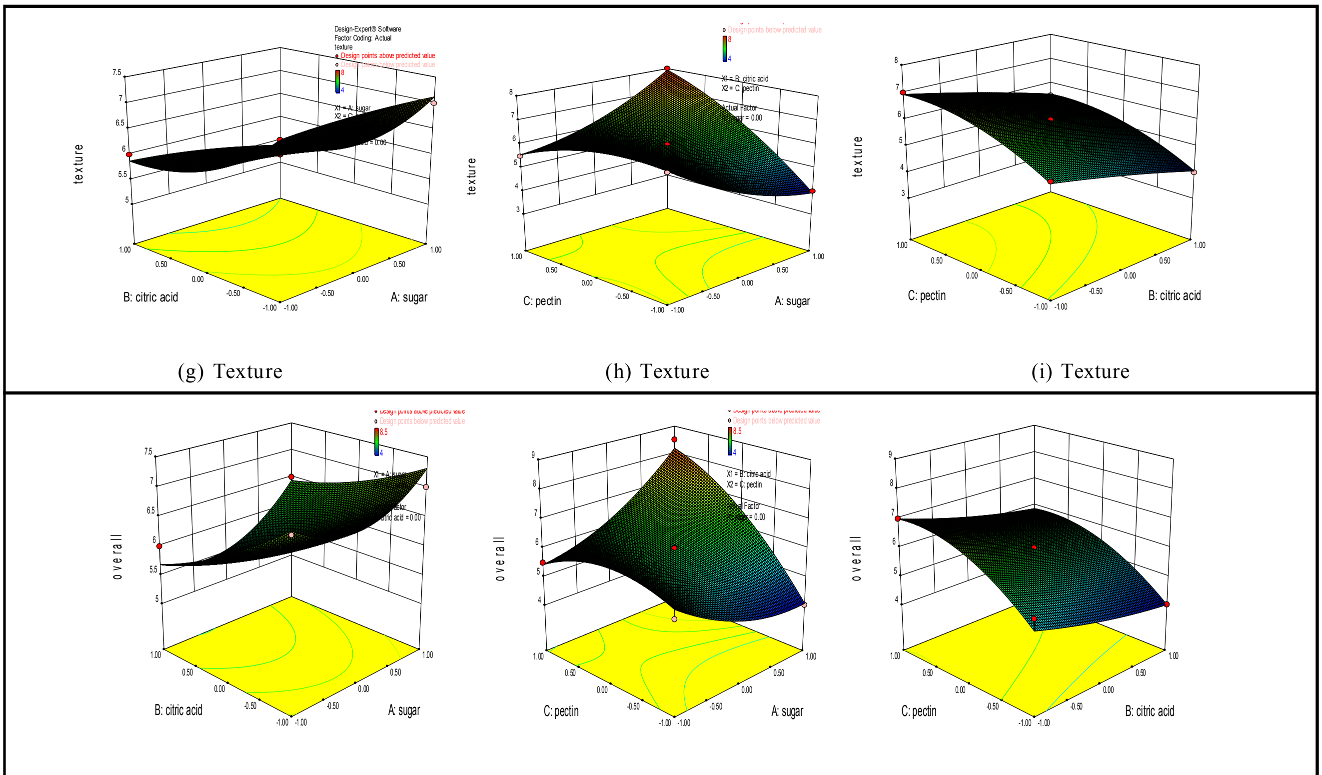
$X_{1,}$ $X_{2,}$ X_3 and Y denote sugar (%), citric acid (%), pectin (%) and corresponding response, respectively.

According to the predictive models for sensory attributes (Table 5), optimization was carried out by generating 3D graphs for each sensory attribute as shown in Figure 3. A maximum acceptable sensory score of 8.0 for all sensory parameters was considered essential to develop good quality leather from litchi affected with pericarp browning. 3-D graphs give the effect of different levels of sugar, citric acid, and pectin on sensory scores (Figures 3 a-l). Increasing the concentration of sugar from 25 to 37.5% irrespective of pectin level reduced the sensory scores for appearance of leather, whereas the further increase in the level of sugar increased the scores, but this effect, was more pronounced with 1.5% pectin (Figure 3a). Color of the litchi leather becomes darker as the concentration of sugar increases and pectin decreases (Figure 3b). It can be also recorded that increasing the concentration of citric acid, decreased the odor (c, d), taste (e, f) and texture (g, h, i) scores of the product irrespective of sugar and pectin concentration. Figures 3 (j, k, l) also indicates that increasing the level of citric acid decreases the scores for the overall acceptability whereas the increasing level of pectin enhanced the overall acceptability of leather samples irrespective of sugar concentration.



(a) Appearance (b) Color (c) Odor

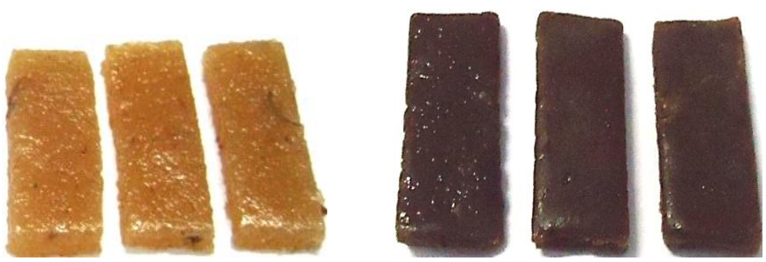
(d) Odor (e) Taste (f) Taste



(g) Texture (h) Texture (i) Texture

(j) Overall acceptability (k) Overall acceptability (l) Overall acceptability

Figure 3: Effect of different levels of sugar, citric acid and pectin on different sensory parameters of litchi leather.



At 0 day After 12 months

Figure 4: Effect of different levels of sugar, citric acid and pectin on different sensory parameters of litchi leather.

3.3 Process optimization

The results obtained by the experimental design showed that fitted models for all sensory parameters were suitable to describe the experimental data. Multiple response optimizations were done to maximize all sensory scores. After analysis, the optimized process conditions for preparation of litchi leather were 50% sugar, 0.8% citric acid and 1.5% pectin. At these conditions, maximum scores for appearances, color, odor, taste, texture, and overall acceptability were obtained, showing predicted values of 8.03, 8.43, 7.84, 7.84, 8.40 and 8.49, respectively. The optimized results were validated to determine the adequacy of the second-order polynomial models and found that these values were in very close proximity to the observed values (Table 6).

3.4 Storage stability of optimized litchi leather

The changes in TSS, moisture, acidity, non-enzymatic browning, sensory analysis, and microbial quality of litchi leather during 12 months of storage are presented in Table 7. The percentage of acidity and non-enzymatic browning of litchi leather significantly ($p \leq 0.05$) increased during 12 months of storage. However, TSS and moisture were non significantly affected in ambient storage conditions.

As observed scores of almost all the sensory attributes exhibited a decreasing trend during the storage period of 12 months (Table 7). Statistical analysis, however, implies that organoleptic scores pertaining to different sensory attributes were at par up to 2-8 months of storage of leather when compared with those of freshly prepared litchi leather.

Table 6: Predicted and observed values of various parameters of litchi leather

Responses	Organoleptic scores					
	Appearance	Color	Odor	Taste	Texture	Overall acceptability
Predictive value	8.03	8.43	7.84	7.84	8.40	8.49
Observed value	8 ± 0.5	8.96 ± 0.16	7.9 ± 0.27	8.4 ± 0.2	8.3 ± 0.2	8.3 ± 0.25

Table 7: Effect of storage at ambient conditions on different parameters of litchi leather

Storage period in months	Physicochemical and microbial parameters					
	TSS (%)	Moisture (%)	Acidity (%)	Nonenzymatic browning (OD at 440 nm)	Total Viable Count (cfu/g)	Yeast and Mould count (cfu/g)
0	74.00 ± 0.2	15.60 ± 0.02	1.36 ± 0.01	0.0140 ± 0.2	ND	ND
2	74.00 ± 0.01	15.30 ± 0.01	1.36 ± 0.02	0.0193 ± 0.2	ND	ND
4	75.33 ± 0.01	14.70 ± 0.02	1.68 ± 0.02	0.0260 ± 0.3	ND	ND
6	75.33 ± 0.1	14.46 ± 0.02	1.77 ± 0.01	0.0300 ± 0.1	ND	ND
8	75.33 ± 0.2	14.23 ± 0.01	1.81 ± 0.01	0.0323 ± 0.1	ND	ND
10	78.00 ± 0.02	13.33 ± 0.03	1.94 ± 0.01	0.0380 ± 0.2	ND	ND
12	78.0 ± 0.02	13.00 ± 0.02	1.98 ± 0.02	0.0423 ± 0.1	ND	ND
CD	NS	NS	0.21*	0.013*	-	-
Sensory parameters						
Storage period, in months	**Appearance**	**Color**	**Odor**	**Taste**	**Texture**	**Overall acceptability**
0	8.93 ± 0.27	8.93 ± 0.25	7.93 ± 0.2	8.40 ± 0.15	8.23 ± 0.2	8.30 ± 0.12
2	8.93 ± 0.1	8.50 ± 0.22	7.93 ± 0.21	8.36 ± 0.13	8.10 ± 0.22	8.30 ± 0.16
4	8.66 ± 0.1	7.83 ± 0.2	7.86 ± 0.18	8.13 ± 0.17	7.96 ± 0.16	7.90 ± 0.11
6	8.10 ± 0.2	7.50 ± 0.15	7.76 ± 0.16	7.76 ± 0.2	7.53 ± 0.17	7.66 ± 0.2
8	7.36 ± 0.15	7.00 ± 0.13	7.50 ± 0.21	7.53 ± 0.2	7.23 ± 0.14	7.03 ± 0.14
10	6.96 ± 0.12	6.43 ± 0.18	7.23 ± 0.23	6.96 ± 0.22	6.76 ± 0.16	6.43 ± 0.21
12	6.33 ± 0.11	5.96 ± 0.2	6.86 ± 0.2	6.50 ± 0.18	6.23 ± 0.17	5.96 ± 0.24
CD	0.29**	0.43**	NS	1.12**	0.42**	0.43**

Average score given by 30 panelists on nine point hedonic scale, **, * significant at 1% and 5% levels of significance, respectively, NS stands for Non-significant and ND stands for Not detected, cfu/g stands for colony forming unit per gram, nm stands for nanometre.

4. Discussion

The change in the external color of litchi as depicted in Figure 2 might be due to loss of anthocyanin and reduction in moisture level (Kumar *et al.,* 2016), but the aril of litchi is not affected by pericarp browning (Sangeeta *et al.,* 2014). Reduction in weight, specific gravity, moisture, acidity and ascorbic acid might be due to desiccation, oxidation of ascorbic acids, and degradation of organic acids whereas the increase in TSS of arils during storage might be due to water losses from the fruits (Chakraborty and Banik, 2003; Qu *et al.,* 2007; Mukherjee, 2005; Singh *et al*., 2010; Sangeeta *et al.,* 2014). Moisture loss from fruits is facilitated by poor skin resistance to water vapor movement, air current, warm temperature, low RH and temperature gradient between the air and fruits. Browning can occur when as little as 2% of the pericarp moisture is lost after harvest (Kumar *et al.,* 2016). Micro-cracking also causes pericarp browning. Ascorbic acid being sensitive to light, oxygen and heat might be oxidized easily in presence of oxygen by both enzymatic and nonenzymatic reactions and hence excessively lost during ambient storage (Lal *et al*., 2010; Thakur *et al.,* 2020). Further, degradation into dehydroascorbic acid or furfural during storage might have caused decrease in ascorbic acid (Gautam *et al.,* 2020). A gradual declining trend in the acidity of litchi fruit with the advancement of storage period at ambient conditions was also observed by Qu *et al.* (2007) and Devi (2009). Results revealed that the total sugar content of arils was increased due to storage of litchi fruits at ambient conditions for two days. These results are in close conformity with the findings of Mukherjee (2005) and Singh *et al.* (2010) who reported increasing trend in non-reducing sugar in litchi cv. Rose Scented stored up to 6th day of storage.

The higher sensory scores for appearance and color of leather with high pectin and sugar with a medium amount of acid concentration level as indicated in Table 2 and Figure 3 might be due to water binding and gel-forming properties of sugar and pectin (Hoagland, 2004). The caramelization reaction produced darker color on leather during cooking process which can be controlled by adding high concentration of pectin which helps in the fast binding of water and sugar together. Changes in odor and taste attributes may be due to the increased sourness of the product with higher levels of citric acid and while the texture rating of leather is invariably decreased with increasing the level of citric acid (Table 2 and Figure 3). It may be due to more amount of acid, losses of the elasticity of fibrils and as a result, the product becomes more syrupy (Manay and Shadaksharaswamy, 2008). According to the literature, pectin is a colloid that has a negative charge. Pectin will clot and form fine fibres. This structure is able to hold liquid. The addition of citric acid in a big amount would decrease the texture response because the texture was runny (Fahrizal, 2014). Citric acid with a pH that is too acidic would give rise to H^+ ions and decreases the number of negative charges which not only lowers the attraction between pectin and water molecules but also lowers the repulsive forces between pectin molecules as a result the ability of pectin to form a stable gel is decreased (Tyagi *et al.,* 2015). These ions (H^+) also cause syneresis, the discharge of water from the gel so that the texture of the leather will decrease or even not form (Sunarharum *et al.,* 2020). The addition of sugar concentration also affects the balance between pectin and water and can reduce the stability of excess pectin in forming fine fibres so, that the texture of leather that formed was not too hard. Overall acceptability of the food products depends on all sensory attributes. Hence, it decreases or increases with fluctuation of other sensory scores.

Coefficient of determination (R^2) is a statistical measure that represents the proportion of the variance for a dependent variable that is explained by an independent variable or variables in a regression model. According to Prashad, (2009) value of R^2 of more than 80% is good for explaining the variability in the sensory data. Thus, the model developed for predicting sensory scores for litchi leather with different ingredient levels was adequate (Table 4). *p*-values are used in hypothesis testing to decide whether to reject or accept the null hypothesis. The smaller the *p*-value, the more likely one is to reject the null hypothesis. *p*-value less than 0.05 indicate model terms are significant. A smaller value of *p* indicates the greater significance of the corresponding variables whereas a high *p*-value indicates that the model has a significant lack of fit and therefore, is considered to be inadequate (Noordin *et al.,* 2004). The models having *p*-value lower than 0.01 (indicating the lack of fit is insignificant at 90 % confidence level) are accepted (Dogan and Okut, 2003).

The positive sign in front of the regression coefficient in the polynomial equation as presented in Table 5 indicates the synergistic effect of independent variables (sugar, citric acid and pectin) on responses (sensory parameters) whereas the negative sign indicates the antagonistic effect (Noordin *et al.,* 2004).

The increase in TSS during storage of litchi leather might be due to the gradual loss of moisture which resulted in increased concentration of total soluble solids in the products (Table 7). In addition to the loss of moisture, the breakdown of complex/organic molecules into simple forms might also be responsible for increased TSS (Safdar *et al.,* 2014). A gradual increase in the TSS of pumpkin leathers packed in different packaging materials was also reported by Dhiman *et al.* (2020). The reduction in moisture content of guava leather during the storage period was also observed by Sandhu *et al.* (2001). Nearly 2% moisture loss was recorded in papaya-tomato (70:30) based leather during three months storage study (Ahmad *et al.,* 2004).

Increase in acidity of leather with the progress in storage period may be due to formation of acid from sugars and other chemical reactions. The increment in acidity was also observed by Dhiman *et al.* (2020) and Parekh *et al.* (2014) in pumpkin leather and fortified mango bar, respectively during ambient storage. Increase in TSS and acidity of guava leather (Sandhu *et al.,* 2001), karonda jelly (Chaudhary *et al.,* 2007), and apricot jam (Touati *et al.,* 2013) during storage have also been recorded earlier. Browning of litchi leather (Figure 4) during storage might be attributed to non-enzymatic browning reactions which ultimately generate brown pigment precursors such as hydroxymethylfurfural (Lespinard *et al.,* 2012). Oxidation of ascorbic acid and the reaction between organic acid and sugars are also considered responsible for developing browning (Hoagland, 2004; Giacalone *et al.,* 2019; Thakur *et al*., 2020). The development of brown coloration in the products during storage may be due to nonenzymatic browning reactions as suggested by Hoagland (2004). Similar results were also reported during storage of sweet papaya chutney (Gupta, 2000), aonla chutney (Choudhary *et al.,* 2011) and mixed pulp of papaya and tomato (Ahmad *et al.,* 2004).

Table 7 depicted a decreasing trend in all sensory attributes after 6 months of storage period. The reduction in score of appearance and color of the leather might be that during prolong storage co-polymerization of organic acids change in the rate of browning reaction within the product occur (Thakur *et al.,* 2020) while reduction in odor score of processed products might be due to the breakdown of complex metabolites into simpler ones leading to volatilization of flavor components (Sivakumar *et al.,* 2005). The possible reason for decrease in texture score of leather was the absorption of moisture from the atmosphere during ambient storage (Dhiman *et al.,* 2020). The loss in sensory scores might lead to decrease in the overall acceptability of litchi leather. No microbial growth was observed during the entire storage of litchi leather because the presence of sugar and pectin bind the free water which reduced the water activity of the product. Vennilla (2004) found nonsignificant changes in organoleptic attributes of guava-papaya (50:50) fruit bars during 180 days of storage. Dhiman *et al.* (2018) reported that pumpkin leather was organoleptically acceptable for a storage period of 5 months.

5. Conclusion

The low-value litchi fruits, *i.e.*, those affected by pericarp browning which lost their market value have great potential in term of nutrient and production of new products. Therefore, reduction in post-harvest loss and utilizing the pericarp deteriorated litchi for the production of value-added products with appreciable shelf-life has great significance for economic growth and the welfare of farmers as well as preserve the litchi nutrients for long length of time.

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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